

AICE, the Atom Interferometry CERN Experiment

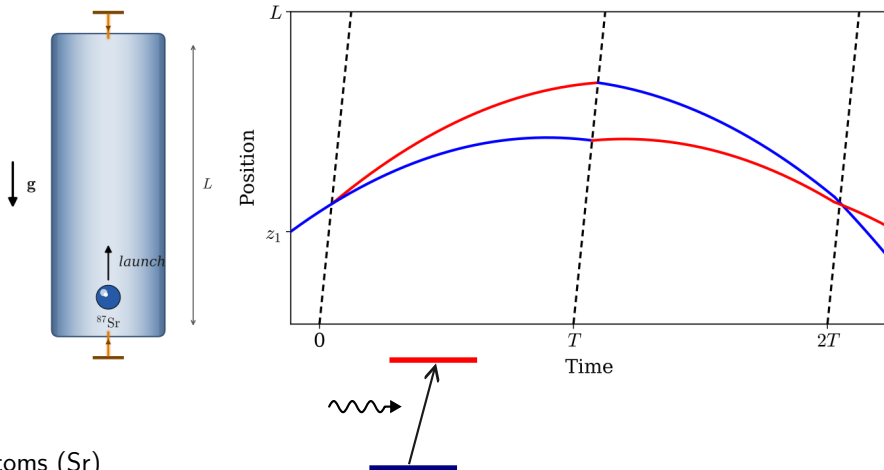
Pierre Cladé and the AICE Community



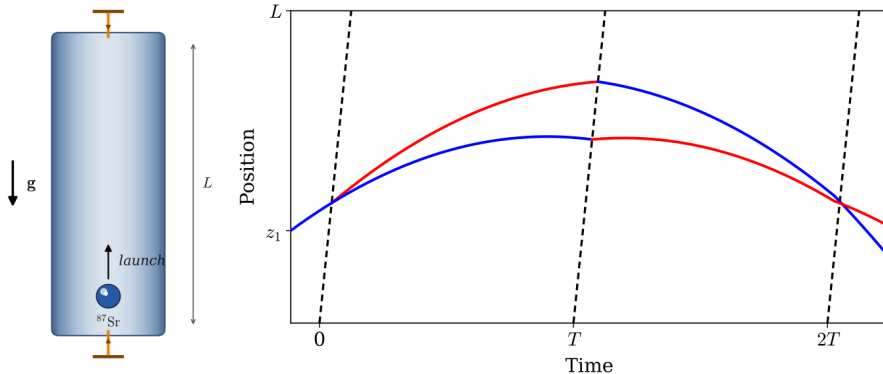
AICE Facility proposal at PX46

Proposal : 140 m vertical atom interferometer infrastructure for Dark Matter and Fundamental Physics





- Cold atoms (Sr)
- Two internal states. Coherent transition driven by the laser (Rabi oscillation)
- Beamsplitter : $|a\rangle \rightarrow \frac{|a\rangle}{\sqrt{2}} + \frac{|b\rangle}{\sqrt{2}}$. Momentum exchange : recoil velocity ($\simeq \text{cm/s}$).



Phase shift

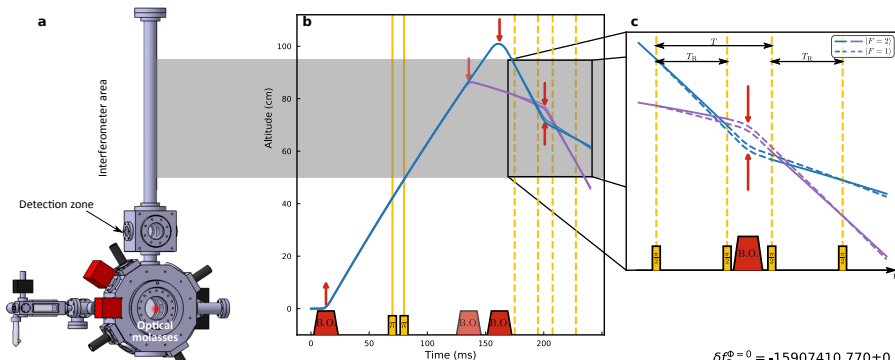
■ Atoms : internal energy + motional energy

■ Laser : $\omega_0 t + \frac{\omega_0}{2c} \gamma t^2$

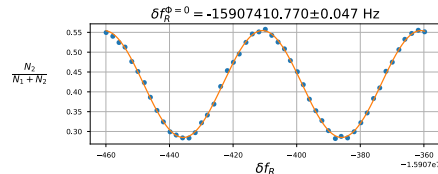
■ $\Delta\Phi = 0 + \frac{\omega_0}{2c} (g - \gamma) T^2$

Quantum gravimeter

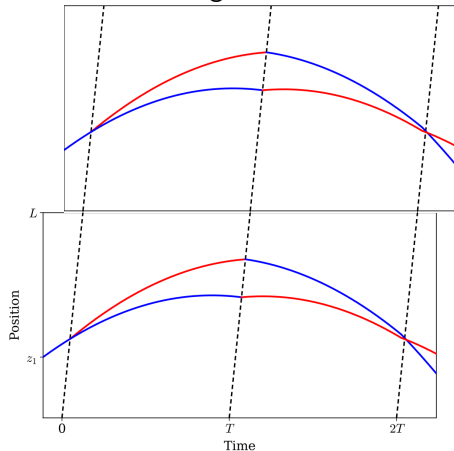
$$\alpha^2 = \frac{2R_\infty}{c} \frac{A_r(Rb)}{A_r(e)} \frac{h}{m_{Rb}}. \text{ Determination of the recoil velocity } \left(\frac{\hbar k}{m_{Rb}}\right). \text{ Doppler effect}$$



Determination of α at 8×10^{-11}



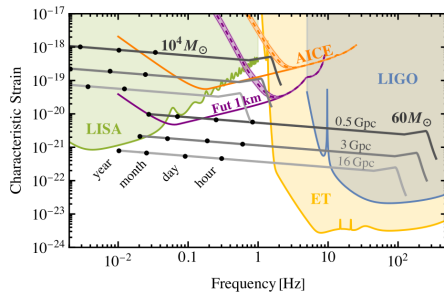
Differential configuration



Gravitational waves in the mid-frequency band :

$$\Delta\phi(t) = 2k_{\text{eff}} h L \sin^2\left(\frac{\omega T}{2}\right) \sin(\phi_0)$$

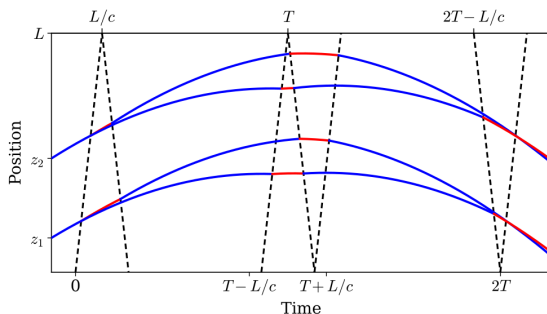
ω is the frequency of the wave



Atoms in a scalar ULDM field

Photon (d_e) and electron (d_{m_e}) coupling : $\mathcal{L}_\phi \supset \phi(t, \mathbf{x}) \sqrt{4\pi G_N} \left[\frac{d_e}{4e^2} F_{\mu\nu} F^{\mu\nu} - d_{m_e} m_e \bar{\psi}_e \psi_e \right]$.

Time-varying electron mass and fine structure constant $\rightarrow$ Time-varying transition frequency : $\omega_A(t, x) \simeq \omega_A + \Delta\omega_A(t, x)$ with $\Delta\omega_A(t, x) \propto \phi(t, x)$



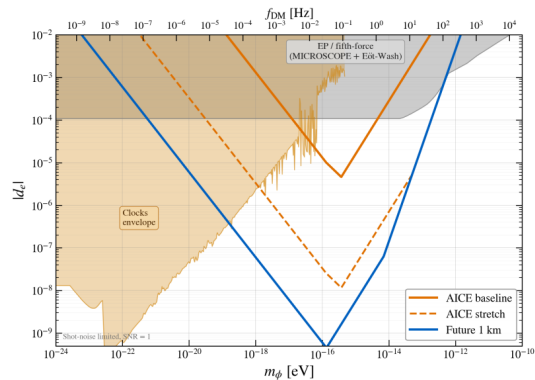
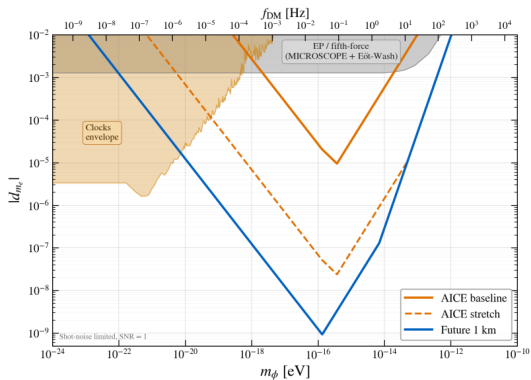
Imbalance between the two interferometers

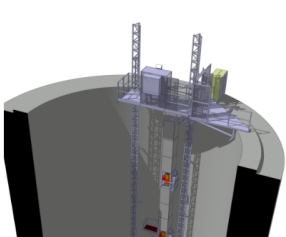
$$\Delta\Phi \simeq 4\overline{\Delta\omega_A} n \Delta_z \sin^2(m_\phi T/2)$$

with

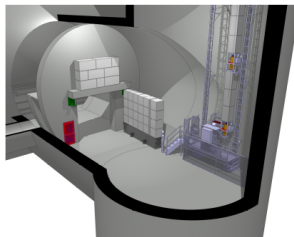
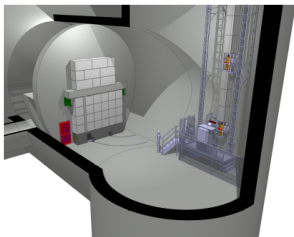
$$\overline{\Delta\omega_A} = \omega_A \sqrt{4\pi G_N} [d_{m_e} + (2 + \xi_A)d_e] \frac{\sqrt{2\rho_{\text{DM}}}}{m_\phi}$$

PRD 105, 023006 (2022)





Elevator platform integrated with the AICE facility



Shielding wall: closed door (left), open door (right)

CERN uniquely combines the mature site, host capability and LS3 window needed to realise Europe's immediate 100 m step on the required timescale.

Class 4 estimate for the Initial strontium configuration, three interferometer sources and one surface reference. MCHF, excluding VAT. Construction only, excluding R&D, commissioning and operations. Rounded to 0.1 MCHF.

Infrastructure and installation (post-LS3)	Cost	Scientific instrument, controls and DAQ	Cost
Long-baseline vacuum incl. telescope vessel	2.0 – 4.0	Atom-source packages (three plus reference)	0.6 – 0.7
Magnetic shielding and field control	1.4 – 2.2	Laser systems incl. high-power amplification	0.9 – 1.3
Mechanical support and installation logistics	0.5	Frequency reference, comb, cavity, stabilisation	0.5 – 0.6
Facility controls, interlocks and networking	0.3 – 0.7	Laser-laboratory optics and beam distribution	0.5 – 0.6
Cooling and ventilation systems	0.8 – 0.9	In-vacuum optics and positioning	0.3 – 0.5
Electrical distribution (post-LS3 phase)	0.1 – 0.2	Experimental controls and monitoring	0.2 – 0.3
Seismic and survey network	~0.10	Imaging and diagnostics	~0.1
SX4 fit-out, furniture and local services	0.5 – 0.6	AICE-specific system integration	0.2 – 0.4
		DAQ, storage and online computing	0.4 – 0.7
		Clock-laser transport and beam conditioning	0.4 – 0.6
Infrastructure subtotal	5.7 – 9.1	Scientific instrument subtotal	4.0 – 5.7
Experiment direct total		9.7 – 14.8	
Contingency (20% of direct cost)		1.9 – 3.0	
Experiment total including contingency		11.6 – 17.8	
CERN LS3 shaft preparation, carried by CERN outside the experiment cost		1.5	
LS3-phase electrical works, outside the experiment cost, attribution to be settled		0.2 – 0.3	
Combined programme total, experiment plus CERN LS3 preparation		13.3 – 19.6	

■ Coordination :

- Project Leader : Oliver Buchmueller (Imperial College)
- Cold Atom Coordinator : Richard Hobson (Imperial College)
- Laser Coordinator : Eduardo Granados (CERN)
- Technical Coordinator : Sergio Calatroni (CERN)
- National representative : France (Andrea Bertoldi, LP2N/IOGS; PC, LKB/CNRS), Germany (Dennis Schlippert, IQO/Hannover; Ben Stickler, Ulm)

■ More on the project :

- Technical Proposal for the AICE Facility : arXiv:2608.18743
- AICE Community Workshop 2026, <https://indico.cern.ch/event/1687915/>

